Claims

1. A method for correlating a vehicle with the road it travels on based on cellular communication comprises of:
   - Learning handover sequences of drives for the relevant routes, together with the location of each handover as a location reference and creating a learnt database.
   - Conducting analysis of new handover sequences from new drives (that do not contain location reference) in conjunction with the learnt database to assign a route at certain time points during cellular phone calls.
2. A method as in claim ('1') where as the method for learning handover sequences comprises of:
   - Handover chains in the learnt database are clustered according to a similarity algorithm so that each cluster contains at least similar N chains (N<=M, N=>1), where as N and M may vary for different route sections.
3. A method as in claim ('2') where as the similarity algorithm comprises of:
   - Each of the chains in a cluster has at least K (K<=L) cells that appear in the same order as in a header, where as K and L may vary for different route sections.
4. A method as in claim ('2') where as ambiguous chain clusters (clusters in which at least one of the chains has similarity to chains related to a different route section) are filtered.
5. A method as in claim ('4') where as clusters have similarity if at least for one of the chains within a cluster (1^{st} cluster) another chain is found in another chain cluster (2^{nd} cluster) that includes at least J (J<=L) cells that appear in the same order, and this chain relates to a different route section than the cluster, where as J and L may Vary for different route sections, both clusters are filtered.
6. A method as in claim ('4') where as a cluster has similarity to a raw data chain if at least for one of the chains within a cluster another chain is found in the raw data that includes at least J (J<=L) cells that appear in the same order, and this chain relates to a different route section than the cluster, where as J and L may Vary for different route sections, the chain cluster is filtered.
7. A method as in claim ('1') where as in the learning phase the accuracy level of a handover is calculated in one or a combination of the following ways:
   - Using signal strength measurements to detect sharp decays in signal strength resulting in a handover and thus determine handovers accuracy level.
   - Measuring the location spread of handovers between the same cells for different trips over the same route to determine handover accuracy level and average location.
8. A method as in claim ('1') where as the analysis stage comprises of:
   - Matching cell chains from new drives to the learnt database by searching for a chain of J cells that has at least K (K<=J) cells that appear in the same order, both in a chain from the new drive as well as in a chain from the learnt database, whereas J and K may vary for different

route sections.

- Assigning the route of the chain from the learnt database to the new chain that was matched.

9. A method as in claim ('8') where as prior to assigning the route of the chain from the learnt database to the new matched chain is done while filtering out those new chains that were matched with two chains or more that relate to different routes.
10. A method as in claim ('8') where as the analysis stage includes a secondary matching procedure that is based on the initial correlation.
11. A method as in claim ('10') where as the secondary matching procedure comprises of matching cells before and after the match we have detected in the initial stage by following the raw data chains in the learnt database backward and forward relative to the matched chain and looking for an L out of M (L<=M) cells match where as M is typically smaller than J, where as L and M may vary for different route sections.
12. A method according to claim ('1') where as analysis is conducted to detect the vehicle location in specific points along the route.
13. A method as in claim ('12') where as the analysis comprises of:
    - Extracting all matching handovers (cell pairs) information of a new chain (location, timing, accuracy) from all the chains in the learnt database that were matched with it.
    - Calculating location and accuracy of each handover in the new chain according to all the handovers from the extracted chains from the learnt database that relate to the same route section and contain the same cell pairs.
14. A method according to claim ('1') where as in the analysis phase after a vehicle is correlated with the road it travels on, further analysis is conducted to detect traffic incidents.
15. A method as in claim ('14') where as if the call have not ended yet and no new handover have been received for time T, the distance D to the farthest possible handover location to a possible next cell is used to calculate the maximal possible speed at the current route section as follows: Max Speed <= D/T. If this speed is bellow a speed threshold S then a possible incident report is issued for this route section.
16. A method as in claim ('1') where as the analysis of new drives is conducted based only on cell ID data.
17. A method as in claim ('1') where as the analysis is conducted based on extraction of handover related messages only from the communication links between the switch and the base station controllers in a cellular network.
18. A method as in claim ('1') where as the analysis is conducted based on extraction of only different percentage of the calls out of different parts of the cellular system.
19. A method for extracting traffic speed for a certain route section based on the rate of handovers (cell switching) for that route section.
20. A method as in claim ('19') where as the traffic speed extraction comprises of:

- A calibration stage in which traffic speed of a route section is correlated with the rate of handovers for this route section on the same time.
- Handovers rate is measured continuously and by comparing to the rate of handovers in the calibration stage the speed for the route section is extracted.

21. A method for generating continuous traffic load map based on vehicle locations at certain time points comprises of:

- Using all the locations and timings per call to find the speed on different route sections over the covered area.
- Using location reports of the same vehicle covering several route sections to achieve higher accuracy for longer distance.
- Using the location, timing and location accuracy data to determine the accuracy level of the speed at the different route sections.

22. A method for generating incident alerts based on traffic load map and incident reports comprises of all or a combination of:

- Using the speed data to generate incident alerts when the speed is bellow S Km/H where as S may vary over time or for different route sections.
- Using Incident reports data to generate incident alerts when the speed is bellow S Km/H where as S may vary over time or for different route sections.

23. A method for generating incident clearance information based on traffic load map and incident clearance reports comprises of all or a combination of:

- Using the speed data to generate incident clearance when there have been an incident in this route section and speed increases significantly
- Using Incident clearance reports data to generate incident clearance information when there has been an incident over a route section and speed increases significantly.

24. A method as in claim ('1') where as the analysis stage comprises of:

- Matching cell chains from new drives to chains in the learnt database
- Filter out new chains that were matched with chains in the learnt database which represent more than one route section

25. A method as in claim ('23') where as the matching procedure comprises of:

- Searching for a chain of J cells that has at least K (K<=J) cells that appear in the same order, both in a chain from the new drive as well as in a chain from the learnt database, whereas J and K may vary for different route sections.
- Assigning the route of the chain from the learnt database to the new chain that was matched.

26. A method according to claim ('24') where as analysis is conducted to detect vehicle location in specific points along the route. This analysis comprises of:

- Extracting all matching handovers (cell pairs) information of a new chain (location, timing, accuracy) from all the chains in the learnt database that were matched with it.

- Calculating location and accuracy of each handover in the new chain according to all the handovers from the extracted chains from the learnt database that relate to the same route section and contain the same cell pairs.

27. A method as in claim ('26') where as in the learning phase the accuracy level of a handover is calculated in one or a combination of the following ways:

- Using signal strength measurements to detect sharp decays in signal strength resulting in a handover and thus determine handovers accuracy level.
- Measuring the location spread of handovers between the same cells for different trips over the same route to determine handover accuracy level and average location.

28. A method according to claim ('26') where as the location in time and accuracy level is used to calculate traffic speed per each route section.

29. A method according to claim ('26') where as the location in time and accuracy level is used to detect traffic incidents.

30. A method according to claim ('1) where as analysis is conducted to detect traffic incidents. This analysis comprises of:

- Collecting handover's time density information for each route section
- Alerting of probable incident whenever density of new chains decrease rapidly

31. A method for correlating a vehicle with the road it travels on based on cellular communication comprises of:

- Learning handover sequences of drives for the relevant route and creating a learnt database.
- Conducting analysis of new handover sequences from new drives (that do not contain route reference) in conjunction with the learnt database to assign a route at certain time points during cellular phone calls.

32. A method according to claim ('31) where as analysis is conducted to detect traffic incidents. This analysis comprises of:

- Collecting handover's time density information for each route section
- Alerting on probable incident whenever density of new chains decreases rapidly.

33. A method according to claim ('31') where as analysis is conducted to detect incident clearance. This analysis comprises of:

- Collecting handover's time density information for each route section
- Notifying on incident clearance whenever, after an incident, the density of new chains increases significantly.

34. A method according to claim ('31) where as analysis is conducted to detect traffic speed. This analysis comprises of:

- A calibration stage in which traffic speed of a route section is correlated with the rate of handovers for this route section on the same time.
- Handovers rate is measured continuously and by comparing to the rate of handovers in the

calibration stage the speed for the route section is extracted.

35. A method for correlating a vehicle with the road it travels on based on cellular communication, comprises of:

- Collecting handover sequences statistics for the relevant area.
- Collecting traffic volume information for each route from external sources.
- Assigning sequences to routes according to volume comparison analysis
- Conducting analysis of new handover sequences from new drives in conjunction with the learnt database to identify a route at certain time points during cellular phone calls.

36. A method as in claim 34 whereas the geographic situation is simple, that the external source to collect traffic volume information can be a map.

37. A method as in claim ('1') whereas the method is used for areas where at least 2 roads are covered, at least partially, by the same 2 or more cells.

38. A method according to claim ('1') where as virtual sensors detect the speed at certain specific locations across routes within the covered area and emulate the communication protocol between traditional road sensors and the control center in a hybrid traffic control system.

39. A method according to claim ('1') where as further analysis is conducted to continuously update the learnt database. This analysis comprises of the follows:

- Estimate the location of handovers within matched sequences that do not appear in the database
- Add new matched sequences to the learnt database

40. A method according to claim ('1') where as further analysis is conducted in order to detect changes in the cellular system and adjust the learnt database as follows:

- Monitor during the operational stage chains or clusters that their rate of matching decreases significantly or are not matched at all.
- Find new clusters that were rarely matched or not matched at all, that appear in the same locations, according to preceding or following chains.
- Compare statistics of number of matches per cluster and find new clusters to replace clusters that are rarely matched.